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**What is visual anticipation and how much does it  
rely on the dorsal stream ?**

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## **Abstract**

The present commentary addresses the function of visual anticipation in ball sports, redefines the concept of anticipation, and examines the theoretical consequences of the redefinition. Visual anticipation has traditionally been defined as the ability to predict a forthcoming event from incomplete cues. In this commentary, however, anticipation is defined as the ability to use prospective information scaled in units of maximum action capabilities. It is argued that the latter definition more faithfully reflects the challenges faced by sportsmen *in situ*. Also, the definition proposed in this commentary emphasizes the importance of dorsal stream functioning, whereas the traditional definition has often led visual anticipation to be related to ventral stream functioning. In line with this redefinition, it is argued that part of the functioning generally attributed to the ventral stream should in fact be attributed to the dorsal stream, even though expertise in ball sports should eventually be characterized by the interacting contributions of the dorsal and ventral streams.

## **Keywords**

Prospective control – Action-scaled information – Dorsal stream – Ventral stream – Visual anticipation – Affordance – Law of control

## **1. Introduction**

Van der Kamp, Rivas, van Doorn, and Savelsbergh (2007) have recently introduced an ecologically-inspired framework for visual anticipation in ball sports. Their framework emphasizes the interacting contributions of the dorsal and ventral systems (e.g., Milner & Goodale, 1995). The framework is based on the idea that the ventral system is involved in perceiving which actions a particular situation affords and the dorsal system in the visual guidance of the action. In this commentary we further discuss the function of visual anticipation in ball sports. More specifically, we redefine the concept of visual anticipation and examine the theoretical consequences of the redefinition.

## **2. Visual anticipation and predictive information**

The majority of studies designed to study visual anticipation have adhered (more or less explicitly) to the definition proposed by Poulton (1957). According to this definition, visual anticipation is the ability to make accurate predictions from partial or incomplete sources of visual information. An example of such an incomplete source of information could be the direction of gaze of a soccer player that is about to take a penalty kick. Poulton's definition has led to the use of paradigms in which the ability to accurately predict a forthcoming event is carefully examined by occluding candidate incomplete sources of information. Although several studies have been successful in showing that high levels of expertise go together with the ability to predict forthcoming events rapidly and accurately (e.g., Abernethy & Russel, 1987; Williams & Burwitz, 1993), van der Kamp et al. (2007) raised an interesting issue: The magnitude of predictive errors, even for experts, often contrasts with the accuracy of related actions.

How can actions be so accurate while the perception of properties that are crucial to the actions are perceived so poorly? A first possibility is that the large perceptual errors were

merely due to technological limitations of the considered experiments. For instance, the use of video recordings of the opponent's movements from the player's perspective might not allow a good immersion of the participants into the environment, with the result that important (predictive) information could be missing. However, similar results have been reported in field settings (Starkes et al., 1995).

A second possibility is that action studies do not show the same errors because of the perceptual-motor mechanisms involved in anticipation. Would it be possible that visual anticipation does not rely on predictive information? An affirmative answer to this perhaps counterintuitive question is suggested by the results of studies reviewed by van der Kamp et al. (2007), and also by recent psychophysical studies. Welchman, Tuck, and Harris (2004) revealed systematic errors in the perception of approaching objects, leading them to question the accuracy of human 3-D perception in general. In addition, Harris and Drga (2005) showed that a perceptual mechanism that is possibly involved in predicting where a projectile is going is not used in ongoing behaviour. Moreover, a recent study by Craig, Berton, Rao, Fernandez, and Bootsma (2006) showed that judgments of the place of arrival of a free kick in soccer in the presence of spin are biased, and that the bias exists for all levels of expertise (i.e., expert goalkeepers, expert players, novices). These different results indicate that the ability to accurately predict a forthcoming event does not necessarily reflect a high level of expertise with regard to related actions.

As a consequence, one might wonder to what extent mechanisms analyzed in studies in which observers have to predict a forthcoming event are representative of mechanisms that are relied on by sportsmen *in situ*. Most probably, perceptual mechanisms that are used *in situ* are often not predictive. Furthermore, as also mentioned by van der Kamp et al. (2007), the perceptual and motor mechanisms involved in fast ball sports cannot be studied in isolation. Numerous studies have shown, for example, that affordances are perceived more accurately if

perceivers engage in ongoing action (e.g., Oudejans, Michaels, van Dort, & Frissen, 1996; Oudejans, Michaels, Bakker, & Dolné, 1996; Cornus, Montagne, & Laurent, 1999). According to Heft (1993), a major problem for studies that focus on the perceptual side of a perceptual-motor task is that they allow for ‘an analytical stance’, which is unrepresentative of the functioning of perceptual-motor mechanisms under normal circumstances. Although the problem of cognitive (in)penetrability of perceptual-motor mechanisms falls outside the scope of this commentary (see for example, Pylyshyn, 1999; Ripoll, 1991; Paillard, 1991; McPherson, 1991), we do want to mention that this ‘analytical stance’ is more likely to be found in the ‘head of a coach’ than in the perceptual-motor mechanisms underlying the control of a given action. Note in this regard that the performance of coaches in prediction tasks has sometimes been taken as a reference level, deemed superior to the performance of at least some players (e.g., Ripoll, 1988).

In short, also following van der Kamp et al. (2007), we believe that experiments have too often been designed in ways that enhance the role of ventral stream functioning as compared to dorsal stream functioning. This is unfortunately because such protocols are not representative of the ‘problems’ that players encounter during games; perceptual information that players rely on is often not predictive and perception and action are always intertwined. The emphasis on ventral stream functioning might have been at least partially due to the general (implicit) adherence to Poulton’s (1957) definition of anticipation. In contrast to van der Kamp et al., we therefore suggest to redefine visual anticipation as the ability to use prospective information scaled in units of maximum action capabilities. In the next sections we address the notions of prospective and action-scaled information.

### **3. Prospective control and perception-action coupling**

If perceptual information is not predictive, then how does it look like? There is theoretical and empirical evidence in favour of the use of prospective information (see

Montagne, 2005, for a review). Prospective information is information about the ‘current future’, that is, it informs the perceiver/actor about the future given that the current state is maintained. As a consequence it informs him/her how to modify (or not) his/her movement. In the case of catching fly balls, for example, a negative optical acceleration informs the catcher that given his/her current velocity, the ball will land in front of him/her; a negative acceleration thus informs the catcher how to change his/her velocity (Michaels, & Oudejans, 1992; McLeod, Dienes, & Reed, 2006). Prospective strategies have been shown to operate also in other tasks, including one-handed catching (Peper, Bootsma, Mestre, & Bakker, 1994; Montagne, Laurent, Durey, & Bootsma, 1999) and intercepting a moving target on foot (Fajen & Warren, 2004; Chardenon, Montagne, Laurent, & Bootsma, 2004; Bastin, Calvin, & Montagne, 2006).

Prospective strategies take advantage of multiple redundant sources of information (including sources of information that are independent of optic flow; e.g., Bastin et al., 2006; Bastin & Montagne, 2005). This allows the participant to produce adaptive behaviour independently of particular task constraints (e.g., Chardenon, Montagne, Laurent, & Bootsma, 2005; Bastin, Craig, & Montagne, 2006). In this context a high level of expertise does not depend on the ability to predict a forthcoming event, but on the ability to optimally exploit the redundant sources of available information, which is to say, on the ability to establish a coupling between the movement and the prospective sources of information.

#### **4. Action modes and the perception of affordances**

Above we have emphasized the importance of prospective information for the control of movements. One might wonder whether some kind of predictive control is still necessary before engaging in an action. This issue is closely related to the choice of an action mode, that is, to affordances (Warren, 1988). In their article, van der Kamp et al. (2007) establish (though implicitly) a link between affordances (i.e., the choice of an action mode) and the

ventral stream on one hand and laws of control (i.e., the control of the action) and the dorsal stream on the other hand, to (try to) get a function/structure mapping. This mapping has been extensively discussed, most notably with regard to the contrasting evidence about the neural pathways underlying the perception of affordances (e.g., Michaels, 2000; Norman, 2002; Young, 2006; Dassonville & Kaur Balla, 2006). Whether the dorsal or ventral stream is relied on while perceiving and using affordances appears to depend on the functional nature of the affordance. For example, the dorsal stream would mainly be involved if affordances concern the actualization of behaviour (Young, 2006). In this commentary we argue that this last function of affordances is of paramount importance in visual anticipation.

Note that we do not deny that the ventral stream might be involved in the selection of action modes, as argued by van der Kamp et al (2007). However, the separation of the selection of action modes and the actual control of actions might in some cases be more complicated than suggested by the examples of van der Kamp et al. A first issue is that numerous studies have shown that affordances are action-scaled; the perception of affordances (e.g., the catchableness of fly balls) is more accurate when the participant is moving (e.g., Oudejans, Michaels, Bakker, & Dolné, 1996). What is relevant to the present debate is the fact that the use of information scaled in action units allows the actor to solve two central problems at the same time, namely, determining the action mode (the ‘what’ problem) and regulating the action (the ‘how’ problem). For example, a pedestrian that approaches a street crossing might directly perceive that the current traffic situation affords “crossing without any change in walking speed” rather than merely perceiving that it affords “crossing” (cf. Oudejans, Michaels, van Dort, & Frissen, 1996). This indicates that choosing action modes and the control of action might be intimately entangled processes, which may make it more problematic to advocate the separate involvement of the two visual systems.



Moreover, new affordance-based models of perceptually guided action have recently been proposed (Fajen, 2005c). These models challenge the classical ‘double process’ view according to which the specification of an action mode precedes the control of the action. These affordance-based models have been illustrated in braking studies. The results show that the participant’s braking behaviour depends on the participant’s sensitivity to his or her action boundaries (Fajen, 2005a; 2005b). Said differently, throughout the execution of the action, the actor remains sensitive to whether the current situation affords breaking, and the control of the action is modified if the situation approaches the limits of the participant’s maximum action capabilities. These models thus claim that affordances are perceived not only before the action, in order to select the appropriate action, but also to monitor the control throughout the execution of the action.

Let us further illustrate the affordance-based models with a second example. In the case of catching fly balls, for instance, current models (e.g., Michaels & Oudejans, 1992) state that velocity changes of catchers are aimed to cancel optical acceleration. One limitation of such models is that they do not take into account the catchers’ maximal running speed, a property that is nevertheless important to discriminate catchable from uncatchable fly balls. Action boundaries (e.g., the maximal running speed) delimit a safe region within which the optical acceleration should be maintained to ensure success. Affordance-based models therefore rely on the detection of these boundaries (Fajen, 2005c). For example, if one waits too long before cancelling out optical acceleration, the required speed might become higher than the catcher’s maximal speed, which would mean that the ball cannot be caught anymore. If, in contrast, one knows his/her action boundaries and maintains optical acceleration within the safe region delimited by the lower and higher boundaries on the speed capabilities, then the catching action would always be possible. Recent evidence suggests that this kind of affordances indeed seems to be used during the unfolding of the action to guide the current

behaviour (Fajen, 2005b; 2005c; Bastin, Fajen & Montagne, submitted). To come back to the central issue discussed by van der Kamp et al. (2007), the fact that the perception of affordances and movement control could belong to one single perceptual-motor process reinforces our feeling that the dorsal stream is greatly involved in visual anticipation in fast ball sports.

A final line of research that might be relevant to the current debate is the mode transition from inferential to perceptual functioning proposed by Runeson, Juslin, and Olsson (2000). These authors argue that novice perceivers function in an inferential mode and that with experience they come to function in a qualitatively different direct perceptual mode. The direct perceptual mode typically goes together with superior performance and with less explicit awareness of how the task is performed. It might be interesting to speculate that the inferential functioning described by Runeson and colleagues is related to the ‘analytical stance’ addressed by Heft (1993). Likewise, the transition from an inferential to a direct perceptual mode might be related to a shift from more ventral to more dorsal functioning (cf., Norman, 2001). This would be consistent with van der Kamp and et al’s (2007) suggestion that the relative contribution of the ventral stream is perhaps more important for novice perceivers and actors than for experts.

## **5. Summary and conclusions**

To summarize, in this commentary we have shown how recent studies lead us to question the traditional definition of visual anticipation. In our view, visual anticipation is not the ability to predict a forthcoming event from incomplete advance cues, but the ability to use prospective information scaled in units of maximum action capabilities. This alternative definition, together with recent affordance-based models of perceptually guided action, indicates the important role of the dorsal stream in visual anticipation. Note that we do not deny the role of the ventral stream, we just want to suggest that part of the ‘work’ generally

attributed to the ventral stream is probably realised by the dorsal stream. To conclude, it should be clear that the perceptual-motor mechanisms addressed in this commentary are influenced also by a different kind of parameters (including strategy, knowledge of the game, etc.), and that the behaviour of players *in situ* cannot be understood without taking into account the interacting contributions of the two streams.

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